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COMMENTARY AND DISCUSSION ARTICLE

Achieving consistency in life cycle assessment practice within the European construction sector: the role of the EeBGuide InfoHub

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Abstract
Purpose The objective of the paper is to discuss the role of a new guidance document for life cycle assessment (LCA) in the construction sector available as an online InfoHub.
Methods This InfoHub derives from the EeBGuide European project that aimed at developing a guidance document for energy-efficient building LCA studies. The InfoHub is built on reference documents such as the ISO 14040-44 standards, the EN 15804 and EN 15978 standards as well as the ILCD Handbook. The guidance document was filled with expertise and knowledge of several experts. The focus was put on providing scientifically sound, yet practical guidance.
Results The EeBGuide InfoHub is an online guidance document, setting rules for conducting LCA studies and giving instructions on how to do this. The document has a section on buildings—new and existing—and a section on construction products. It is structured according to the life cycle stages of the European standards EN 15804 and EN 15978, covering all aspects of LCA studies by applying provisions from these standards and the ILCD handbook, wherever applicable. The guidance is presented for different scopes of studies by means of three study types. For the same system boundaries, default values are proposed in early or quick assessment (screening and simplified LCA) while detailed calculation rules correspond to a complete LCA. Such approach is intended to better match the user needs in the building sector.
Conclusions and recommendations This paper can be viewed as a contribution to the ongoing efforts to improve the consistency and harmonisation in LCA studies for building products and buildings. Further contributions are now needed to improve building LCA guidance and to strengthen links between research, standardisation and implementation of LCA in the construction practice.

Keywords Building assessment · EPD · LCA · Operational guidance · Study types

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1 Introduction

The building sector is a major source of different environmental impacts (e.g. climate change, energy consumption, pollution, etc.) and is increasingly subject of European public

policies, see, e.g. a recent communication on Resource efficiency opportunities in the building sector (EC 2014a). Life cycle assessment (LCA) can be a useful means of assessing the whole life environmental performance of buildings and building products. Europe's construction industry is increasingly using LCA in research projects and daily practice. Building certification schemes like the British BREEAM (2014), the French HQE (2014) or the German DGNB (2014) have started relying on life cycle thinking to assess the environmental performance of buildings. Furthermore, the new European Construction Products Regulation (CPR) allows for LCA to address the new Basic Works Requirement 7 "sustainable use of natural resources", which has been a prerequisite for the marketing of construction products in Europe since January 2013.

The directive mentions that "EPD should be used when available for the assessment of the sustainable use of resources and of the impact of construction works on the environment" (OJEU 2011). In the same time, building product manufacturers willing to make a product's environmental claim or communicate on product's environmental aspects might be obliged to provide an EPD for regulation purposes in some national contexts. This is the case in France from 1 January 2014 (METL 2014) and it will be the case in Belgium from 2015 (CFDD 2013). The subsequent provision of such EPDs will lead to a stock of product-specific environmental information for assessing the environmental performance of buildings. One core requirement for such an application is consistency between data supply (product data/EPD) and data use (building LCA).

Beyond the ISO standards 14040-44 already integrated in the national and EU standards, two main bodies are currently active in disseminating LCA for the construction sector: the Institute for Environment and Sustainability (IES) of the EU Joint Research Centre (EC-JRC), indirectly by defining metrics applicable to all economic sectors, and the CEN/TC 350 "Sustainability of Construction Works" that develops sector-specific standards for the construction sector. On the one side, the European Joint Research Centre (JRC) actively develops and propagates the ILCD handbook (EC 2012). On the other side, the CEN TC 350, mandated by the European Commission has released voluntary horizontal standards, e.g. the EN 15804 and EN 15978 for the assessment of the environmental aspects of new and existing construction works and for defining rules for environmental product declaration of construction products. The EN standards use a modular approach to the life cycle stages of the building or product (production, construction, use and end of life) as shown in Fig. 1.

However, the lack of consistent, practically applicable metrics and guidance for practitioners on how to conduct consistent LCA studies due to the differences between ILCD Handbook and CEN TC 350 standards provisions and different levels of experience of LCA practitioners presents a considerable barrier to the widespread use of LCA in Europe's construction sector.

This barrier to consistency had been identified by the Energy-efficient Buildings European Initiative (E2B EI 2014), who consequently set up the European research project EeBGuide (2012a) to provide metrics and web-based operational guidance for construction-related projects, particularly for use within E2B EI projects that use LCA as an evaluation tool. The main goal of the EeBGuide was to provide scientifically sound yet practical guidance, which incorporated as much existing material as possible, using an interactive InfoHub.

This discussion article present an overview of the approach taken to produce the EeBGuide's InfoHub and illustrates its content. Potential applications of the InfoHub for LCA in the construction field are presented and conclusions drawn.

2 Producing the EeBGuide operational guidance for building LCA

2.1 EeBGuide and the European context of sustainable construction

To understand the contents of the EeBGuide InfoHub, it is useful to understand how it is embedded in the European context of sustainable construction. Figure 2 is a representation of the current, potentially confusing situation relating to EPDs, building LCA, building labelling and legislative activities in the European Union.

LCA is currently used as the basis for product assessments, and especially in providing EPD, which form an important data source for building assessments used in building labelling schemes. This basis is not consistently defined by the various standards and the ILCD Handbook; definitions may conflict, and different approaches to conducting a study may be chosen.

Yet, one core requirement for the multi-scale implementation of LCA in the construction sector (from products to buildings) is consistency between data supply (product data/EPD) and data use (building LCA tools). The InfoHub is intended to help achieve this consistency in accordance with other harmonization projects, e.g. the ECO Platform for European EPDs (ECO 2014) and the SBA Common metrics for building labelling schemes (SBA 2014).

2.2 Methodology to set up the provisions and guidance

In developing the EeBGuide, different important aspects were defined based on the analysis of reference documents, e.g. the ILCD Handbook (EC 2010), the ISO 14040-44 (ISO 14040 2006; ISO 14044 2006), the EN 15804 and EN 15978

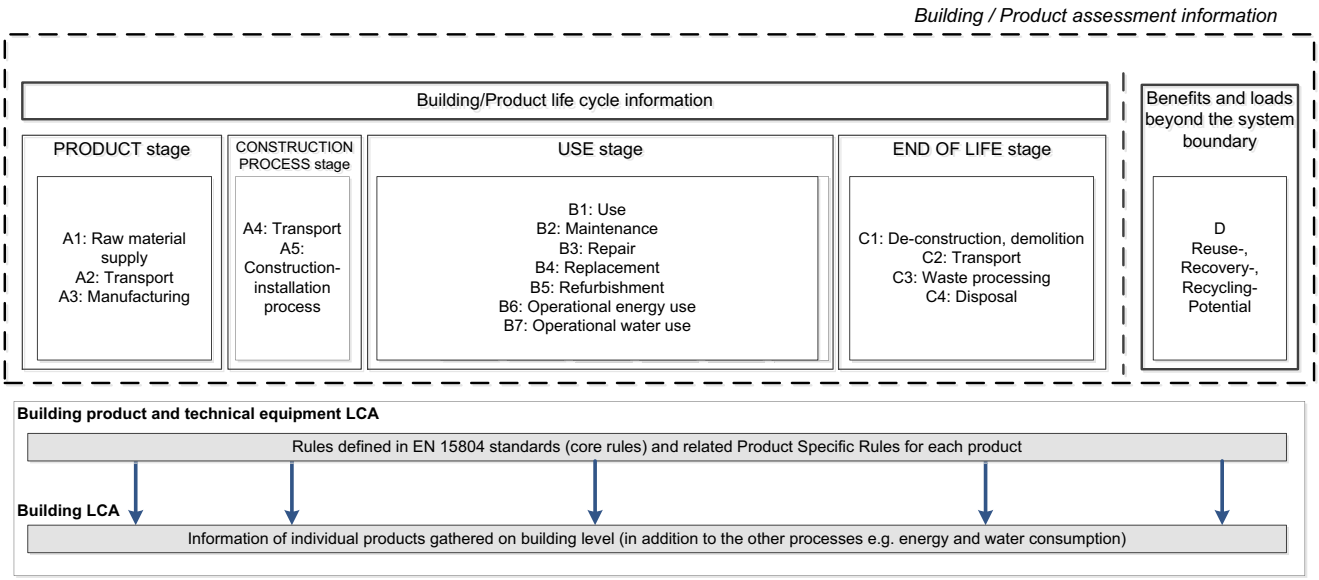


Fig. 1 Relationship between product LCA and building LCA along the life cycle modules (figure adapted from EN 15804 and EN 15978 standards)

standards (CEN 2012a, b) but also other standards, e.g. the ISO 15686 series for service life prediction of building products (ISO 2011) and literature searches (e.g. relevant scientific reports or articles from previous building LCA projects, e.g. ENSLIC-Building (2014), PRESCO (Peuportier et al. 2004; PRESCO 2014), LoRe-LCA (Lore-LCA 2014; Peuportier et al. 2011), annex 31 IEA (2014) and consultation of LCA experts during working meetings). For example, aspects such as the definition of the functional unit for a building product, the use of EPD data in building LCA studies, the end-of-life scenarios, the choice of environmental indicators and the normalization step led to many questions that needed to be addressed, and provisions and guidance clearly documented. Figure 3 presents the approach developed for the EeBGuide InfoHub and applied as far as possible to every "important" aspect.

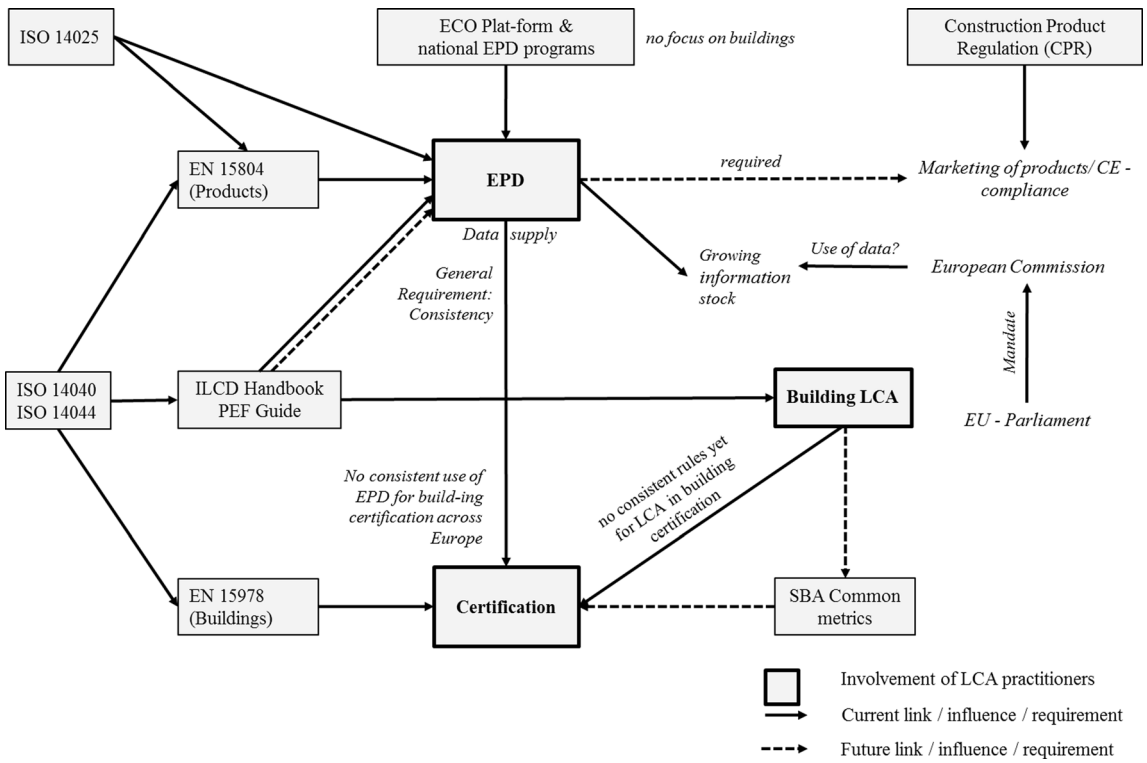


Fig. 2 European situation in the context of EPD and building LCAs

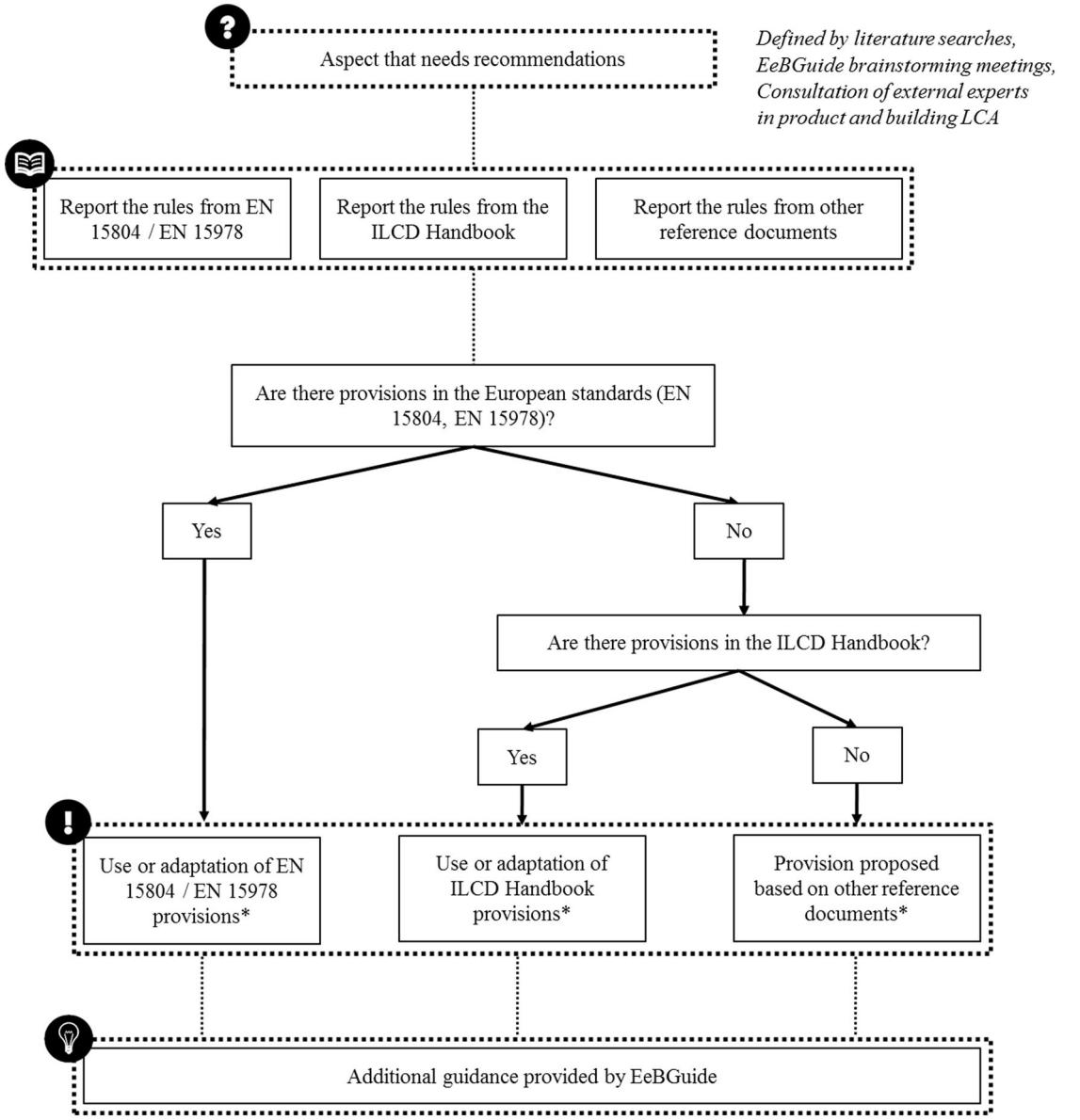


Fig. 3 Methodological approach for the EeBGuide guidance document InfoHub

Each aspect was identified and documented with provisions, rules from the ILCD handbook and EN 15804/EN 15978 standards and detailed guidance with links to relevant information. Wherever possible, any requirement mentioned in the reference documents was included in the EeBGuide. Substantial guidance was proposed if there was none in the reference materials. One of the major benefits of the approach taken by the EeBGuide was that guidance from several LCA experts (including EeBGuide partners, experts from academics, industry and consultancy firms) could be incorporated for every aspect. The experts' insights captured many years of experience and enabled the EeBGuide to give enhanced support to building LCA practitioners.

The validity of the EeBGuide was ensured by the involvement of external reviewers of the EeBGuide's contents. Additionally, two expert workshops and an online public consultation were carried out in 2012 to collect feedback on the guidance document (EeBGuide 2012c, d). During the first expert workshops, 73 aspects and issues were identified and 51 resolved representing nearly 70 % resolution. The unsolved issues were discussed and solved during the second expert workshops. The public consultation ran for 2 months,

for which there were more than 500 downloads of the guidance document. Although only a relatively small number of those that downloaded the consultation documents formally submitted feedback, the high quality of these respondents, and the detail that they went into, was very valuable and has led to some positive and strategic changes to the guidance document.

2.3 Definition of study types for different goal definition

LCA has been developed as a flexible system that can be adjusted to answer different kinds of question (CALCAS 2009). In this context, standardization is always a difficult task, as it is done under a specific goal definition (e.g. EN 15804 is developed to give rules for EPD). As a result, for some key aspects, such as goal definition, following the ILCD Handbook may lead to provisions that are more comprehensive than those in the EN 15804/EN 15978 standards. Consequently, the EeBGuide has two related objectives: (1) remain "flexible" for different studies going beyond the rules of the CEN TC 350 standards and (2) be structured according to the modular principles of the EN 15804/EN 15978 standards.

Within the second objective, the EeBGuide provides three study types for the implementation of the two standards in practice: screening, simplified and complete LCA. It should be borne in mind that LCA studies cannot be completed in the construction sector with the same level of detail as in other sectors. Users such as architects and design engineers require dedicated tools that can be adapted to the specifics of a building project and to their needs. An architect during an architectural competition may conduct a "Screening" LCA for supporting his/her design selection, whereas at a more advanced stage of the building project a "Complete" or detailed LCA may be required, for example, to meet the requirements of a building assessment scheme. These different iterations will not necessarily be performed by the same stakeholder. In each case the data, methodology and results need to be adapted to the goal of the study and to the stakeholder's requirements.

In the EeBGuide, the development of screening and simplified LCA is expected to be based on knowledge gathered from previous detailed building LCA studies, e.g. use of statistical ratio in screening LCA. For all study types, the system boundaries are the same, e.g. from cradle to grave. The only difference between complete LCA and the other two types is that screening and simplified LCA are limited in data input to give the LCA practitioner more time to explore a greater range of initial designs whilst acknowledging that there are more uncertainties in the results than for a complete LCA. The EeBGuide presents recommendations for conducting these types of study and for using them to support design choices (EeBGuide 2012a).

It is important to note that the aim of the EeBGuide study types is not to arbitrarily omit a life cycle stage or focus on a single indicator (e.g. carbon footprint) but rather to enable greater flexibility within the time available and increase the opportunity to explore more design options before carrying out a full LCA on the final building design. The intention is that the LCA practitioner can use existing scientific evidence showing, for example, that a life cycle stage, or an activity (such as demolition), is negligible in the final detailed LCA results of a building type to focus the screening or simplified LCA. The EeBGuide includes quotes from published scientific studies analysing the accuracy of simplified LCA, e.g. Kellenberger and Althaus (2009).

Figure 4 presents the three study types in relation to the goal and scope for a system boundary with different impact sources for a building: the embodied impacts due to the products and equipment from cradle to grave (modules A, B and C), the operational impacts driven by energy consumption (module B6) and water (module B7), and the construction and deconstruction activities (modules A4–A5 and C1). Such a distinction by lifecycle stage enables the LCA practitioner to quickly identify any hotspots. Depending on the goal of the LCA, module D can be developed to quantify potential benefits and loads for recycling, reuse and recovery beyond the life cycle (not reported in Fig. 4).

3 Overview of the EeBGuide InfoHub

In total, 173 aspects were identified and documented with provisions, rules from the ILCD handbook and EN 15804/EN 15978 standards, and detailed guidance with links to relevant information.

3.1 Structure of the EeBGuide InfoHub

The InfoHub is a web-based structure with different sections. A systematic procedure for the description of each important aspect was developed in order to set up the web-based guidance document. Figure 5 presents the template used to describe each important aspect according to the methodological approach presented in Fig. 3. As an example, we reported a part of the aspect related to the definition of system boundaries for existing buildings' LCA.

The guidance document is structured in several parts:

- Guidance for general LCA (goal and scope definition, inventory analysis, impact assessment, interpretation, reporting)
- Guidance for the EN 15804 and EN 15978 life cycle stages (modules A, B, C, D)
- Guidance for building products, existing buildings or new buildings
- Guidance for screening, simplified and complete LCA

To ease the navigation through the InfoHub, icons were created depending on the validity of the aspects, e.g. is the

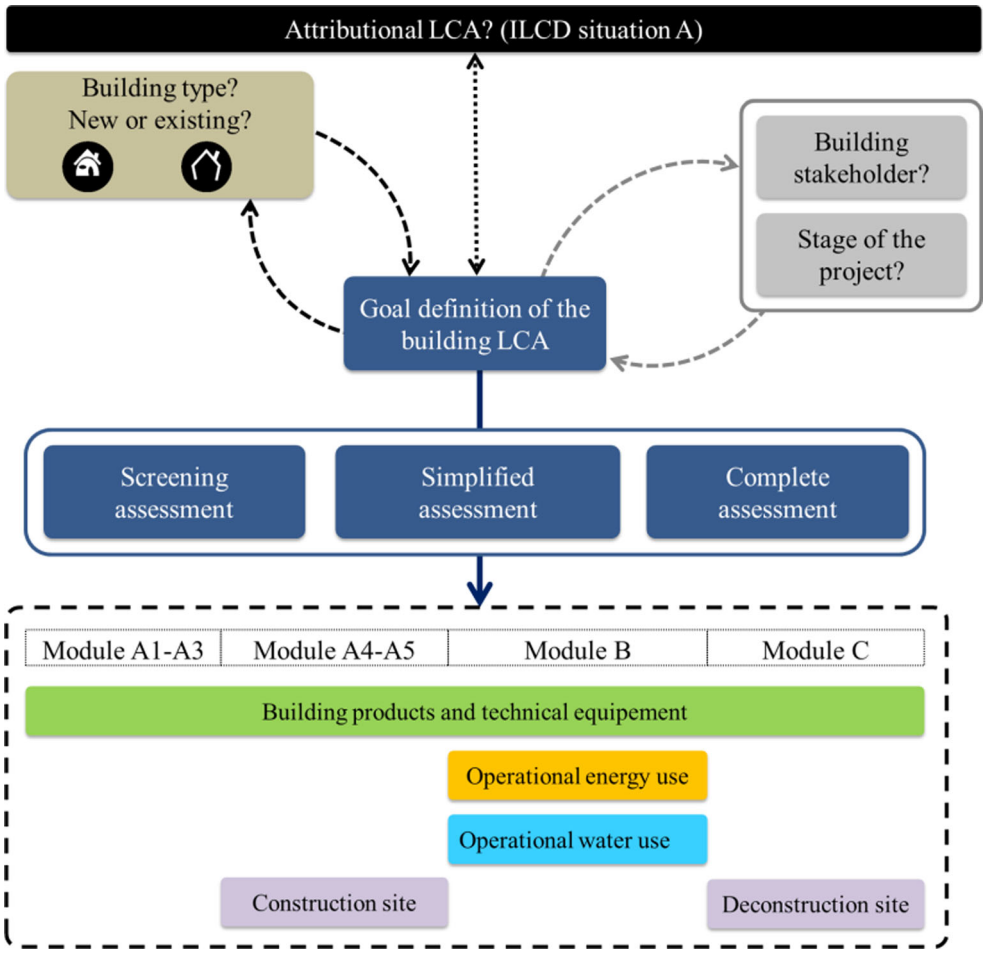


Fig. 4 Approach to develop the three study types: screening, simplified, and complete LCA according to the stage of the project, the building stakeholder, the building type

aspect relevant for new buildings, existing buildings or relevant for a screening or complete LCA (see Fig. 5)?

In the InfoHub, online filter functions allow practitioners consulting the relevant piece of information depending on their needs (EeBGuide 2012a). As it is beyond the scope of this discussion article to address all provisions and guidance, the reader is invited to consult the online InfoHub and look for the corresponding aspect depending on his/her field of interest.

3.2 Website traffic

Figure 6 presents the country of origin of the connections to the EeBGuide InfoHub website. More than 48,000 pages have been viewed which represent around 18,000 visitors from December 2012 to January 2014 (14 months). Looking at similar initiatives, these figures are similar to the SB Alliance website traffic (20,000 visitors) (SBA 2014). As some connections could not be tracked back from a single European country, some referred to the European Union

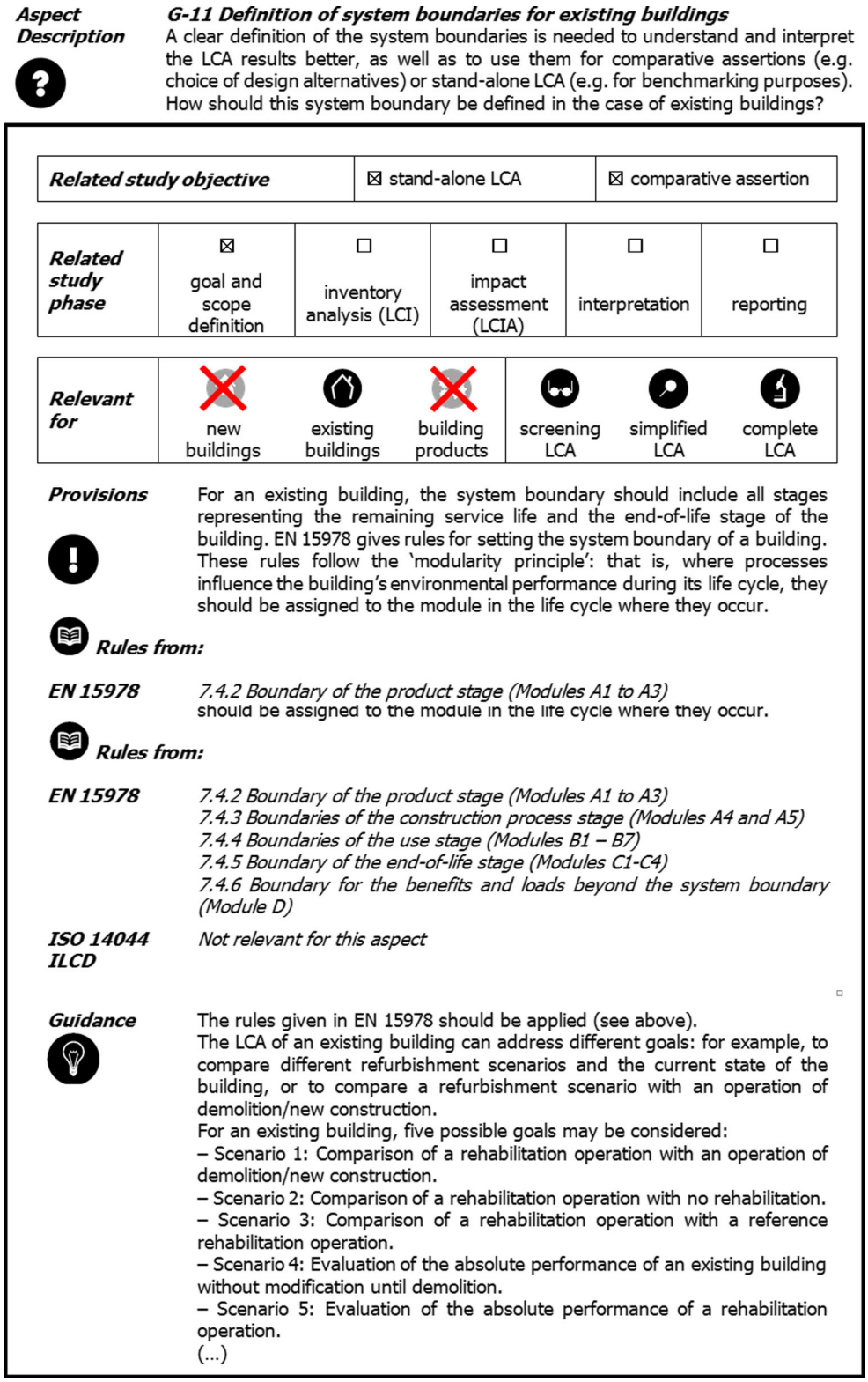
The traffic of the website is not negligible for such a technical website. It can be correlated to the growing amount of projects and initiatives using or dealing with the LCA approach since the 1990s as illustrated for the scientific publications by Guinée et al. (2013). The high interest from the USA could be due to the fact that the next version of LEED will finally include LCA-related parts (LEED 2014). Similarly, the important connections from Ukraine can be related to the development of a local version of the German labelling scheme DGNB while the high connections from France can also be related to current national projects using LCA for the new generation of the HQE Performance labelling scheme (HQE 2014a).

4 Opportunities for the EeBGuide to aid further harmonization of LCA in the construction sector

4.1 EeBGuide as a web-based platform between research, standardisation and practice

The EeBGuide InfoHub provides a bridge between research and implementation of LCA in the construction practice. It is a contribution that follows previous initiatives, e.g. a summary of ongoing and future research studies for the LCA construction sector has been recently proposed in Lasvaux

Fig. 5 EeBGuide systematic template used to describe each important aspect



Aspect Description ***G-11 Definition of system boundaries for existing buildings***

A clear definition of the system boundaries is needed to understand and interpret the LCA results better, as well as to use them for comparative assertions (e.g. choice of design alternatives) or stand-alone LCA (e.g. for benchmarking purposes). How should this system boundary be defined in the case of existing buildings?

Related study objective	☒ stand-alone LCA	☒ comparative assertion

Related study phase	☒ goal and scope definition	☐ inventory analysis (LCI)	☐ impact assessment (LCIA)	☐ interpretation	☐ reporting

Relevant for	new buildings	existing buildings	building products	screening LCA	simplified LCA	complete LCA

Provisions

For an existing building, the system boundary should include all stages representing the remaining service life and the end-of-life stage of the building. EN 15978 gives rules for setting the system boundary of a building. These rules follow the 'modularity principle': that is, where processes influence the building's environmental performance during its life cycle, they should be assigned to the module in the life cycle where they occur.

Rules from:

EN 15978

7.4.2 Boundary of the product stage (Modules A1 to A3)
should be assigned to the module in the life cycle where they occur.

Rules from:

EN 15978

7.4.2 Boundary of the product stage (Modules A1 to A3)
7.4.3 Boundaries of the construction process stage (Modules A4 and A5)
7.4.4 Boundaries of the use stage (Modules B1 – B7)
7.4.5 Boundary of the end-of-life stage (Modules C1-C4)
7.4.6 Boundary for the benefits and loads beyond the system boundary (Module D)

ISO 14044 ILCD

Not relevant for this aspect

Guidance

The rules given in EN 15978 should be applied (see above).
The LCA of an existing building can address different goals: for example, to compare different refurbishment scenarios and the current state of the building, or to compare a refurbishment scenario with an operation of demolition/new construction.
For an existing building, five possible goals may be considered:
– Scenario 1: Comparison of a rehabilitation operation with an operation of demolition/new construction.
– Scenario 2: Comparison of a rehabilitation operation with no rehabilitation.
– Scenario 3: Comparison of a rehabilitation operation with a reference rehabilitation operation.
– Scenario 4: Evaluation of the absolute performance of an existing building without modification until demolition.
– Scenario 5: Evaluation of the absolute performance of a rehabilitation operation.
(...)

et al. (2014) and Ventura and De La Roche (2012) based on the outcomes of the first international LCA Construction conference.

EeBGuide also aids the effectiveness of links being developed (1) between research and standardisation activities and (2) between national EPD programmes particularly through the activities of the ECO Platform (ECO 2014). However, as the implementation of the EN 15804 and EN 15978 standards increases, further contributions are needed near-term to ensure continued sharing of good practice. To that purpose, ongoing

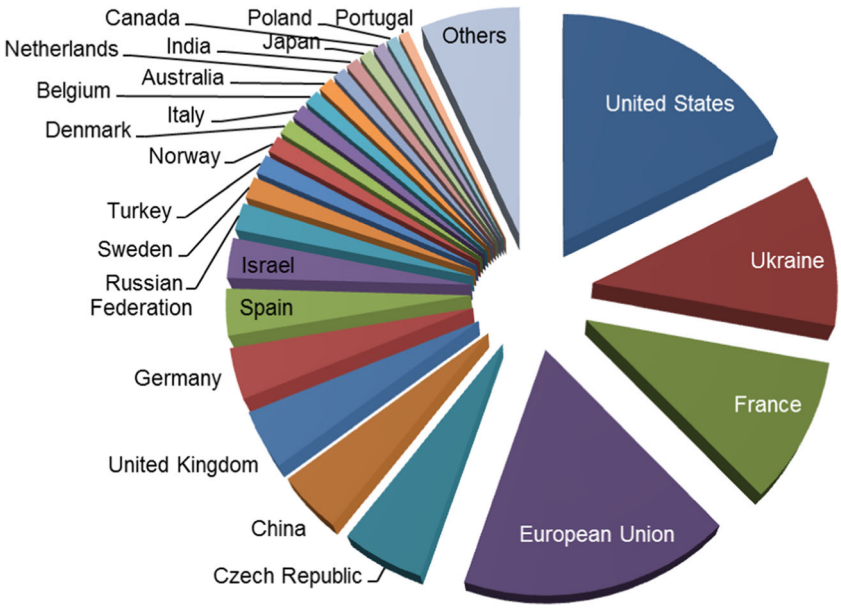


Fig. 6 Breakdown of country of origin in the connections to the EeBGuide InfoHub from December 2012 to January 2014

work is being conducted within the CEN TC 350 committee, e.g. by the development of guidance documents of EN 15804 and EN 15978 standards (CEN 2013a), the development of national appendix of these standards or related standards (AFNOR 2014a, b) and the writing of product specific rules by the different products' TC (CEN 2013b). They will provide additional guidance on how to solve some aspects of the building LCA calculations. The ECO Platform works also provide further harmonization levels, e.g. by defining a common template and mutual recognition rules for verification of construction products' EPDs in Europe.

The guidance should also benefit from feedback from LCA practitioners on the applicability of the recommendations in building projects. To that purpose, development of building-levels tools is essential (see Section 4.2).

4.2 Aiding the development of building-level tools and assessment schemes

EeBGuide supports consistent and harmonized building LCA rules also developed by the SB Alliance (SBA 2014). A key outcome of the EeBGuide is the proposal for three study types: screening, simplified and complete LCA of buildings. It is important that tool developers produce systems that are able to support this, so that the level of detail undertaken reflects the stage of the construction project moving from simplified to complete as the building design becomes clear. Tools also need to be able to support goal definition including both the LCA of a new building and the LCA of an existing building (EeBGuide 2012d, e, f). To aid the LCA practitioner and the move towards comparability, tools will need to implement the CEN TC 350 standards framework for building LCA, e.g. breaking down the life cycle stages into module A (production and construction process), module B (use) and module C (end of life). Implementing consistent scenarios for module D represents a considerable challenge but assessing the recycling potentials of different options can potentially help in the early design stages for comparing different scenarios of design for dismantling or design for recycling. The EeBGuide's guidance is also a source of information for tool developers including interpretation methods and reporting templates (EeBGuide 2012g).

The proper implementation of CEN/TC 350 standards also requires feedback from the data providers to be sure the parameters used in the EN 15804 and EN 15978 standards are actually extractable from the background data (e.g., ecoinvent, GaBi, ELCD, etc.). A guidance document being prepared by the CEN TC 350 committee should help achieve this point (CEN 2013a, b).

For activities for which data availability is currently poor, e.g. on construction processes and deconstruction activities, close cooperation with stakeholders is needed, such as construction companies to provide real data for building-level LCA tools. Without such collaboration, it will be difficult for a building LCA tool developer to get accurate data for the assessment of these contributors or for building-level schemes to properly address their contribution to the building's impacts.

4.3 A blueprint for use within European countries' research programmes and tool development

The EeBGuide InfoHub provides a framework that can be deployed by national building LCA projects and initiatives in Europe. In this section, examples are given for the French, German and Spanish contexts.

In France, the Benefis project (2014), funded by the national research agency, reused the approach developed by the

EeBGuide concerning the study types: screening, simplified and complete LCA. Whereas the InfoHub gives general guidance, the French project focused on more nationally applicable guidance by developing adapted study types for building LCA tools according to the expected user needs (Lasvaux et al. 2013). LCA tool developers have also been informed of the EeBGuide InfoHub and some of them have begun to analyse the guidance. For instance, the ELODIE LCA tool (CSTB 2014) has started implementing study types according to the EeBGuide for the assessment of embodied impacts, operational energy and water use. For embodied impacts, the study types have been redefined according to the construction companies needs and validated in Bonnet et al. (2014). Additionally, initiatives looking at how LCA can be used during the design phases of a building project also reused the concepts of screening, simplified and complete LCA studies (ADEME 2013). Lastly, from a labelling scheme's perspective, the HQE Association launched a pilot test concerning the LCA of 115 new buildings in order to calculate reference values for the French context (HQE 2014a). The rules of this pilot test are consistent with the EeBGuide, EN 15978 and SBA common metrics. The rules also provide the basis for the development of a future LCA performance-based labelling scheme called HQE Performance (HQE 2014b). A similar pilot test has been launched for the LCA of existing buildings in 2014, allowing a deepening of the EeBGuide guidance, e.g. for system boundaries' definition (EeBGuide 2012f).

In Germany, the application of the EeBGuide study types is currently not expected within the DGNB system, but the descriptions of the building materials included in the two possible ways of the DGNB system to assess the building match the system boundaries of EeBGuide "Simplified" and "Complete" LCA. DGNB has also adapted the latest EN 15978 requirements and the environmental impacts have to be broken down into the stated life cycle stages. LCA tool developers in Germany plan to take a close look at EeBGuide and analyse aspects for inclusion in their software. Of special interest are the definitions of the study types for both products and buildings and the proposed solutions for energy production-related issues. In addition, the building LCA software "SBS Building Sustainability" (SBS) plans to fully integrate the study types and also the reporting templates defined by EeBGuide.

In Spain, the EeBGuide InfoHub has been used for the development of SOFIAS, a software tool for assessing the environmental impact of buildings. SOFIAS is the main result of a national project (IPT-2011-0948-380000) developed by a private–public consortium with the financial support of the Spanish Ministry of Innovation and Competitiveness. The users of this software (mainly architects and building engineers), which is planned for release in 2014, will be able to apply different study types depending on the phase of the building's development, e.g. design, construction or operation.

4.4 Beyond the European construction sector

It is likely that the EeBGuide and the concepts proposed in the EN 15978 standard, e.g. the modularity principle of life cycle stages may also be used outside Europe, e.g. in North America. A recent communication from the Athena Institute highlights this point (Athena 2014).

4.5 Beyond the EeBGuide InfoHub: links with current European Commission initiatives

Since 2012, the European Commission has launched other initiatives for the environmental assessment of products and buildings. One of these initiatives concerns the release of a new reference document known as the Product Environmental Footprint (PEF) guide for the harmonization of EPD of all European economic sectors (EC 2012, 2013). This document has recently caused considerable debate within the LCA community on whether it contributes to proliferation of different rules or to harmonization of LCA in Europe especially when considering the construction sector (CEPMC 2013; Finkbeiner 2014; Allacker et al. 2013; Gantner et al. 2013; Galatola and Pant 2014). To date, it is still not clear what the link between the PEF Guide, the EeBGuide and the CEN TC 350 standards will be. Similarly, the European Commission has launched a consultation on sustainable buildings with a view to creating EU-wide measures to achieve better environmental performance of buildings (EC 2014a). This initiative is highly welcome but we think it should be based upon existing works from the CEN TC 350 (e.g. EN 15978 standard), from research projects' results such as EeBGuide and SBA, and from the different labelling schemes, e.g. BREEAM, DGNB, HQE or VERDE (GBCE 2014).

As both initiatives from CEN and JRC do not have currently the same goal and scope, we hope that a converging process will take place to improve the existing contributions (e.g. the EeBGuide InfoHub) for implementing the LCA in the building operational practice.

5 Conclusions and perspectives

The EeBGuide InfoHub enabled the creation of an interactive platform in between research activities (EU projects, others national research projects, scientific conferences), standardisation activities (CEN TC 350 standards), tools' developers and the practical implementation of LCA in the construction sector by the different stakeholders. The guidance document is accessible for free as a web-based interactive document with filter functions to facilitate its use. It also provides links to further detailed information sources, training materials and reporting templates.

The EeBGuide InfoHub is only an intermediate contribution to increase the use of LCA in the construction sector. Further work is needed to refine such an operational guidance. The lack of constant maintenance is currently the major limitation of the InfoHub. In that context, the new European Commission call Europe 2020 (EC 2014b) may serve as an opportunity to launch further LCA-related projects (or projects with a LCA workpackages) to go beyond the EeBGuide project and to expand the guidance towards new scales of assessment (e.g. at the urban level) and towards new modelling perspectives (e.g. for dynamic and consequential construction LCA studies).

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